Wisconsin DNR Forest Health 2019 Annual Report

Ash killed by emerald ash borer, wet forest converting to marsh.

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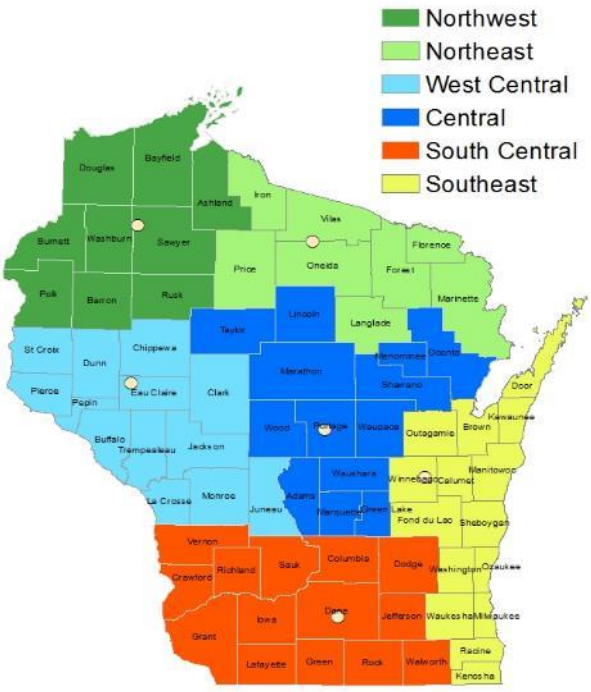

Figure 1. Locations and zones of forest health specialists as of Dec. 2019.

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Staff update

In 2016, **Mark Guthmiller** retired after 26 years as forest health specialist for the southwestern counties, but this summer he rejoined the team as pathology lab assistant. We were all delighted to welcome him back: his cheerful competency and historical knowledge of forest pathogens in WI were a wonderful return to the team.

Strategic Direction of the Forest Health Program

The Forest Health Program provides technical expertise in the prevention, detection, assessment, management and monitoring of invasive plants, insects and diseases that damage trees and forests, and the benefits they provide. The program assists public and private landowners in their efforts to minimize the establishment and adverse impacts from invasive plants and destructive forest insects and diseases. Strategic planning for Forest Health has focused efforts on management guidelines, historical data analysis in the annual report and key intra-agency partnerships.

In 2019, two revised guidelines were implemented on January 1st: "Guidelines for stump treatment to reduce the risk of introduction and spread of Heterobasidion root disease in Wisconsin" and "Emerald Ash Borer Silviculture Guidelines." Trainings on the guidelines were conducted around the state throughout the year for DNR staff and external partners.

Reducing the spread of invasive species on Wisconsin DNR managed lands is a top priority. The Wisconsin State Parks welcome over 14 million visitors a year, and sometimes invasive species hitch a ride. The Forest Health Program partnered with the DNR Bureau of Parks and Recreation on four specific projects in 2019. Invasive Amur cork trees were removed from the MacKenzie Education Center. Hazard tree training was restructured to better serve Parks employees. Emerald ash borer biological controls were released at Peninsula and Kohler-Andrae state parks as part of the integrated pest management of the destructive beetle. EAB Management Plans were developed in partnership with Governor Dodge and Wildcat Mountain state parks.

The Forest Resource in Wisconsin

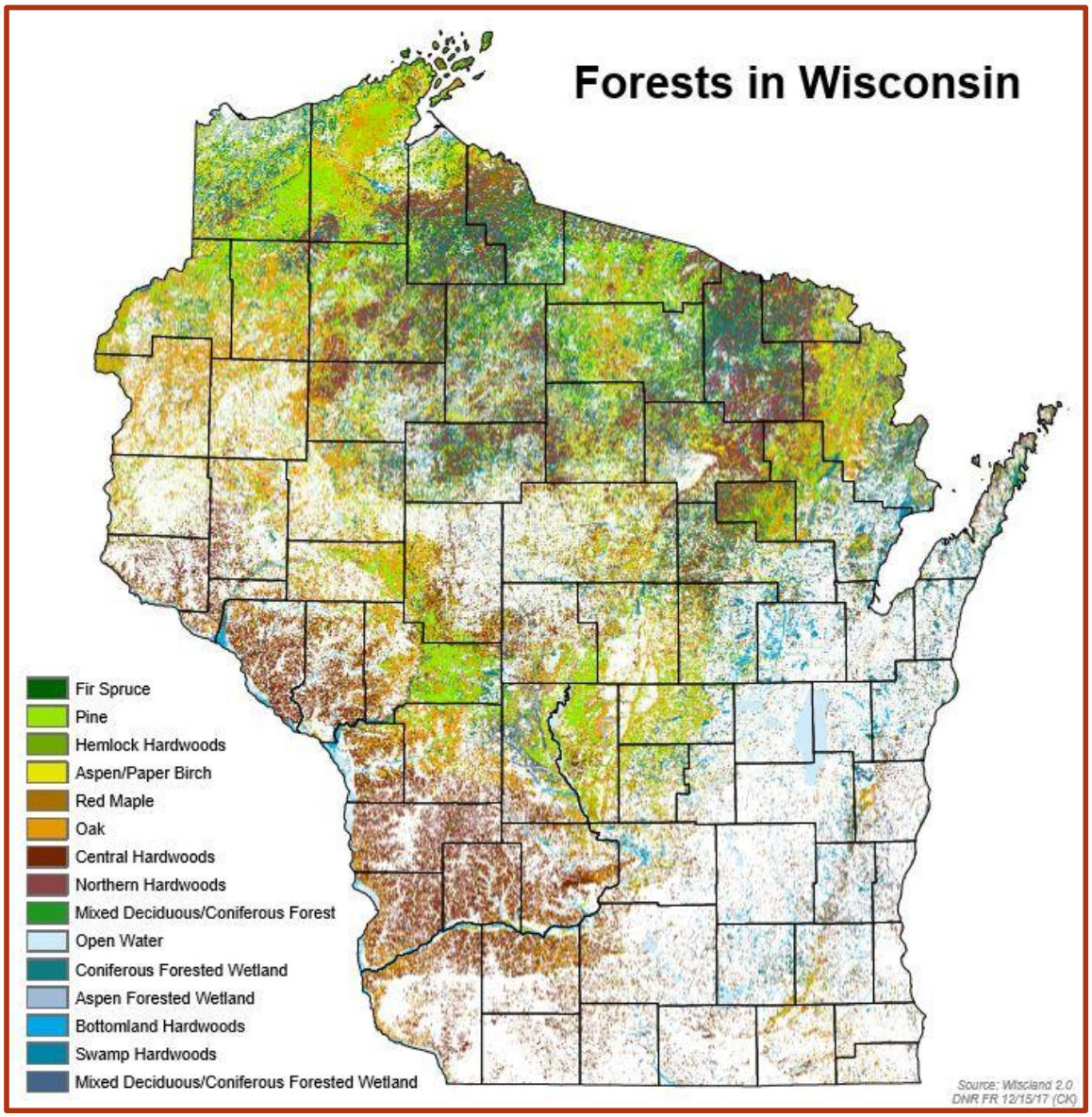


Figure 2. Wisconsin forest cover map. Source: WISCLAND land cover, Wisconsin Dept. of Natural Resources, 2017 (latest version).

Wisconsin's forests are critical for providing wildlife habitat, clean air and water, reducing erosion, and improving the quality of life in urban and rural areas. Forests are also important to the economy of Wisconsin for wood products, recreation and tourism. Current information on the forest resource in Wisconsin is available at dnr.wi.gov.

The area of forestland in Wisconsin has steadily increased in recent decades and currently stands at approximately 17 million acres up by 500,000 acres since 2016 (Figure 3). This is an increase of 1.3 million acres since 1996 and 2.3 million acres since 1983. Wisconsin now has more forested area than at any time since the first forest inventory was conducted in 1936. Over 46% of the state's land area is forested, primarily in the northern and western areas of the state.

Wisconsin's forests are composed primarily of hardwood species. The most abundant forest types are oak-hickory at 26% of total forested acreage; maple-beech-birch at 23%; and aspen-birch at 18% (Figure 3). Conifer types, mainly pine and spruce-fir, represent about 18% of the forested area. Wisconsin forests are for the most part mature with the greatest proportion of stands in the 61-80 year class. About two-thirds of Wisconsin's forest lands are privately owned. The remaining third is split between federal, state, local government and tribal ownership.

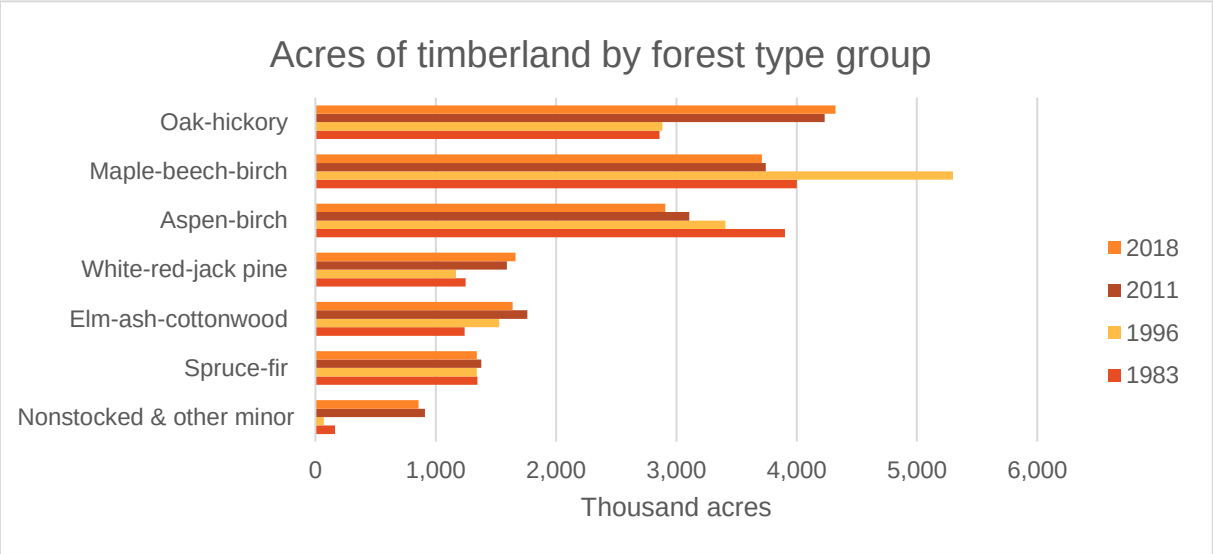


Figure 3. Wisconsin timberland area by forest type (FIA data, US Forest Service).

Outreach and Education

Outreach and education are tools frequently used by the forest health program to engage the public in prevention and management efforts with topical social media posts, blog articles and news releases. The forest health team made greater use of social media in 2019 than in years prior, allowing for rapid communication of forest health concerns to a diverse audience. During the reporting period, eight Facebook posts generated a total of 35,300 direct interactions (likes, comments, clicks, etc.) and appeared in the newsfeeds of over 350,000 Facebook users. The team also published 46 blog articles in the reporting period and increased their blog subscriber base by nearly 1,000 readers. The team attributes this increase to actively recruiting new readers through distributing sign-up sheets at presentations, advertising in a statewide publication for landowners and by prominently displaying the sign-up information on the DNR Forest Health website. News releases were met with more mixed success with wide variation

between articles in how many media sites republished them. The communications specialist is exploring ways to better reach the public with this approach. A total of six news releases generated 12 articles from the media, and the links posted to DNR's Twitter feed engaged almost 180 individuals.

Exotic Species Issues

Beech bark disease

Beech bark disease is a fatal disease of American beech (*Fagus grandifolia*). It is a disease complex of a scale insect (beech scale, *Cryptococcus fagisuga*) that causes wounds that are subsequently infected by either of two fungi in the genus *Neonectria* (*N. faginata* and *N. ditissima*). Both the scale and *N. faginata* are European in origin but *N. ditissima* is native to North America. In 2009, heavy infestations of beech scales and mortality of beech were detected for the first time in Wisconsin in Door County. In surveys done in 2012-13, beech scale was found to have spread through most of the Wisconsin range of American beech. The first confirmation of a *Neonectria* spp. on a beech tree in association with beech scale infestation and beech mortality in Wisconsin was in 2017 in Door County. Door County remains the only Wisconsin county where both components of beech bark disease have been found and where mortality from the disease has occurred in Wisconsin (Figure. 4).

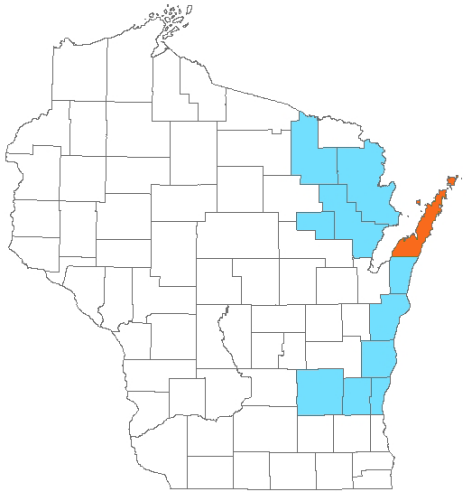


Figure 4. Counties with beech scale detections are shown in blue. Mortality from beech bark disease is limited to Door County in orange.

In 2019, site visits within the range of beech in eastern Wisconsin indicated that populations of beech scale remained very low in counties other than Door County. Subjectively, scale populations in Door county appeared to be declining in areas where they were formerly abundant. Aerial surveys done in late July recorded no premature yellowing of beech indicative of beech bark disease stressed and dying trees as seen in past years.

Jumping worms (*Amynthas* spp.)

"Jumping worms" is a term used for a group of similar Asiatic worms with an annual lifecycle. Invasive earthworms in the genus *Amynthas* were first identified in Dane county in 2013 and have since been reported in 45 of the state's 72 counties (Figure 5). Verified species in Wisconsin are *Amynthas tokioensis*, *A. agrestis*, and the closely related, though larger, *Metaphire hilgandorfi*, first identified in September 2017. *A. tokioensis* is the most common of the three species. *A. agrestis* typically appears in combination with *A. tokioensis* but rarely on its own. Jumping worms have been found primarily in urban or residential areas. This may reflect their long distance spread by people moving plants, mulch and soil for use around their homes.

Or it may be due to reporting bias; there is no formal survey for jumping worms in Wisconsin. All specimens are submitted by the public and are typically collected near where the submitter lives.

In the summer of 2018, researchers with the University of Wisconsin Arboretum began a two-year project on potential control options for jumping worms, funded by the DNR Forest Health Program. Treatments tested were Early Bird fertilizer, biochar and diatomaceous earth. Early Bird is an organic, low nitrogen fertilizer used on golf course greens that acts as a vermicide. Preliminary data compiled by Brad Herrick and Marie Johnston indicate moderate mortality rates in adult jumping worms with the use of Early Bird fertilizer but no measurable effect from biochar or diatomaceous earth. Unfortunately, in 2019, the maker of Early Bird fertilizer stopped production. The researchers substituted Tea tree meal, the primary ingredient and suspected vermicidal component of Early Bird. Tea tree meal is high in saponins and these may be the cause of the injury seen in worms treated with Early Bird fertilizer. This project will continue through July 2020.

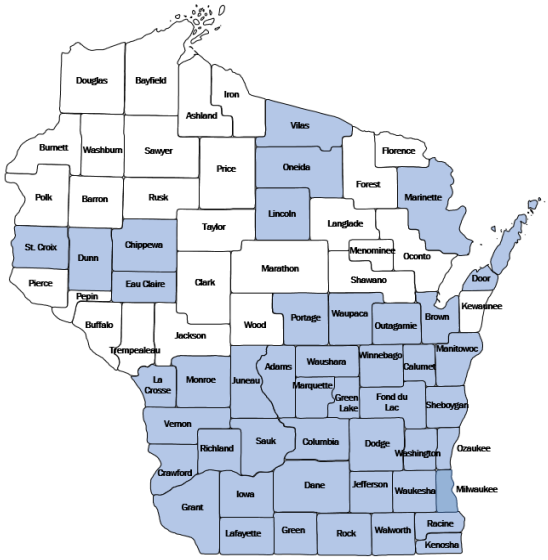


Figure 5. Tinted counties represent the distribution of jumping worms in Wisconsin 2019.

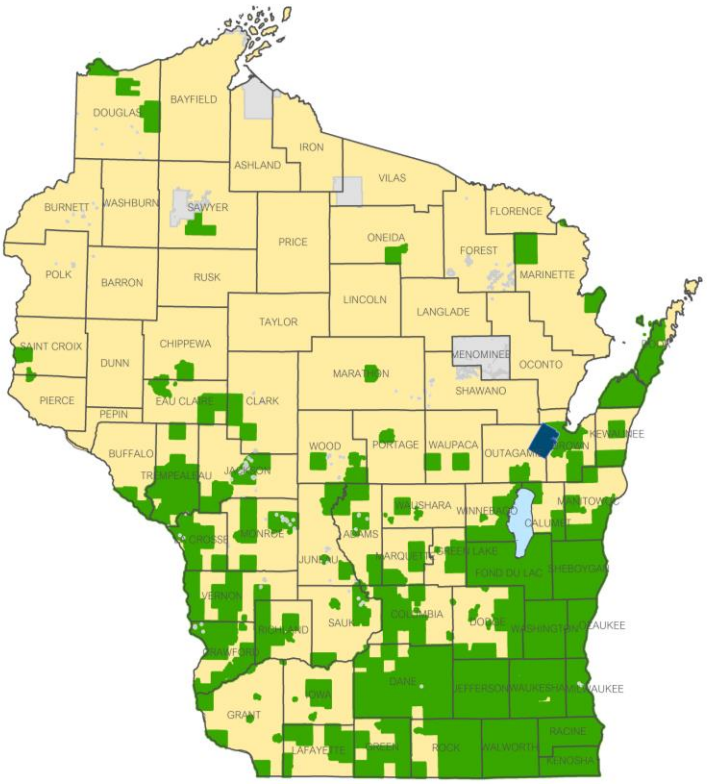


Figure 6. EAB has been confirmed in municipalities indicated in green or dark blue for tribal land. Gray indicates a tribal jurisdiction where EAB has not been confirmed.

Emerald ash borer (EAB, *Agrilus planipennis*)

Distribution of EAB in Wisconsin

In 2019, EAB was confirmed for the first time in Pierce County on the western border of the state (Figure 7). The was no change in quarantine status as the entire state was placed under quarantine in spring of 2018. State agencies continue to record subsequent finds at the municipal level and these indicate that the pest continues to spread within known infested

counties (Figure 6). Subsequent confirmations are made from samples sent in by arborists, community foresters and the public and are identified by DNR or University of Wisconsin Extension staff. For a historical review of the spread of EAB in Wisconsin since its initial identification in 2008, see the report on this species in the Wisconsin DNR Forest Health 2016 Annual Report and subsequent annual reports. There was no trapping for EAB by federal or state agencies in the summer of 2019, though some counties trapped for EAB on their county forest land for use in planning harvests.

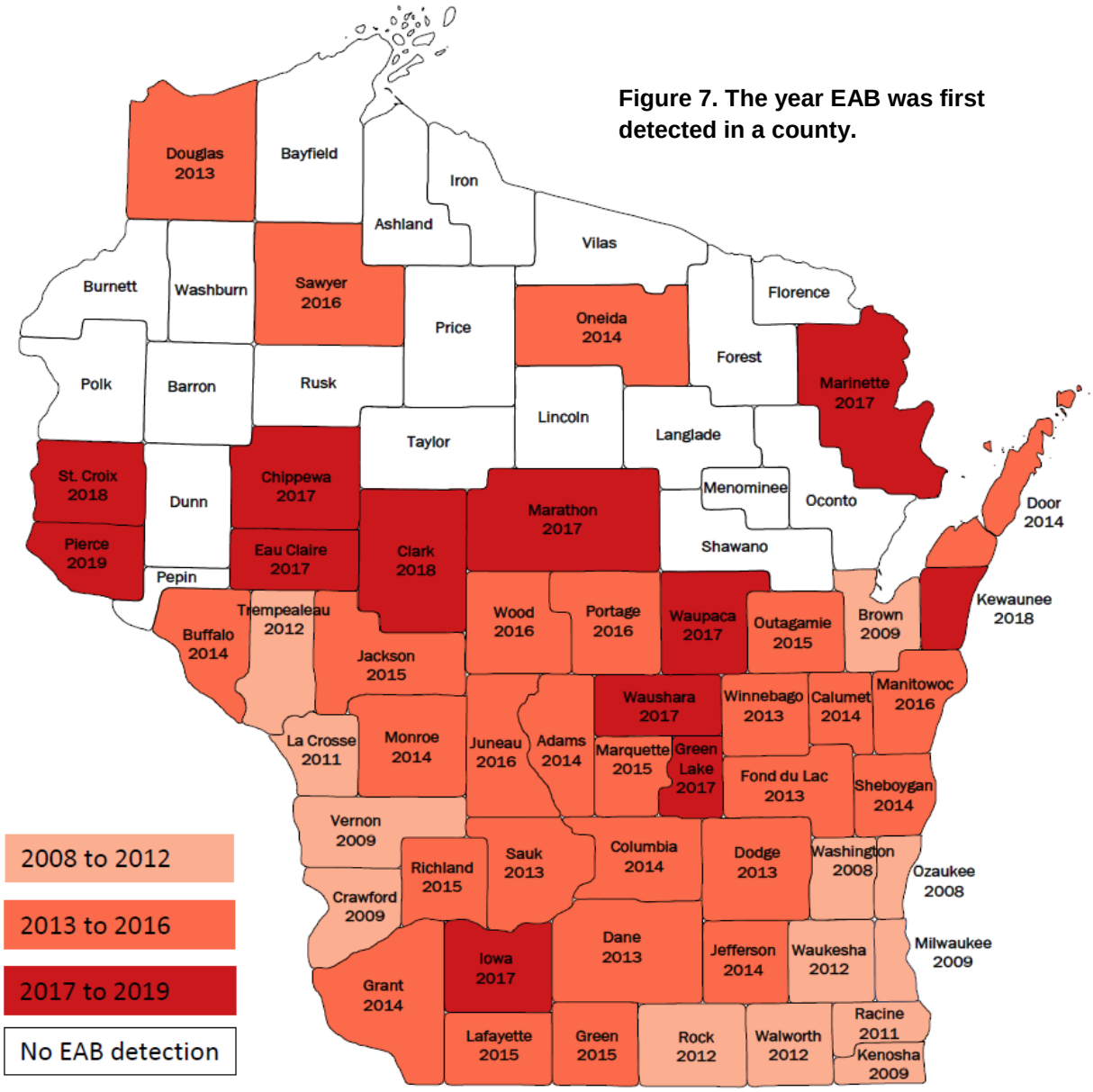


Figure 7. The year EAB was first detected in a county.

Damage from EAB in Wisconsin

Tree decline and mortality increased dramatically in 2019 across southern Wisconsin counties (Figure 8). Area where decline predominated increased to ~66,344 acres in 2019 from ~32,224 acres in 2018. High water levels in many parts of the state may have contributed to stress in EAB infested trees. The acreage where mortality dominated increased to ~95,046 acres in 2019 from ~50,983 in 2018 despite ~77,504 acres in the southeastern counties coming to be dominated by ash that died in previous years. For the first time, mortality of the population of ash in several counties is now considered to be >90%: Ozaukee, Kenosha, Racine and

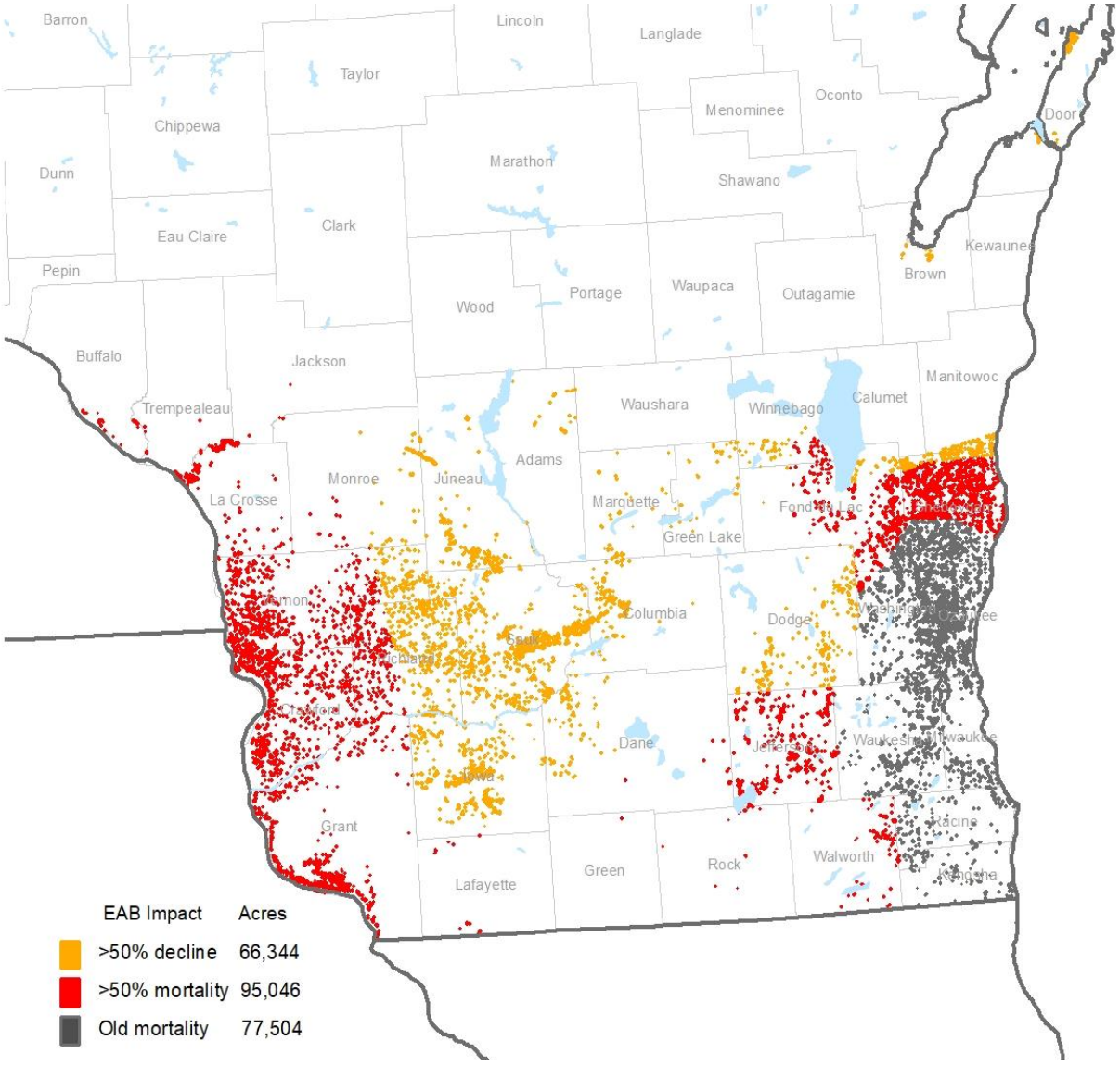


Figure 8. 2019 damage from EAB to ash. Area where damage occurred is overlaid with location of ash giving a stippled appearance. Crown decline predominated in areas marked in yellow. Mortality predominated in areas marked in red. Mortality that occurred in previous years predominated in areas tinted gray.

Walworth and old mortality dominates in adjoining areas (gray stippling). Decline and mortality among ash from EAB has been recorded since 2015 in these four southeastern counties. (Figures 9-12).

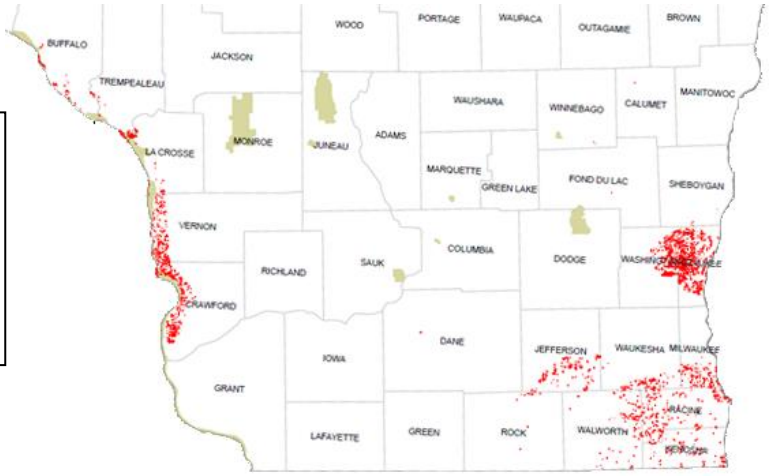


Figure 9. 2015 damage from EAB to ash. Decline and mortality are combined and marked in red. Area where damage occurred is overlaid with location of ash giving a stippled appearance.

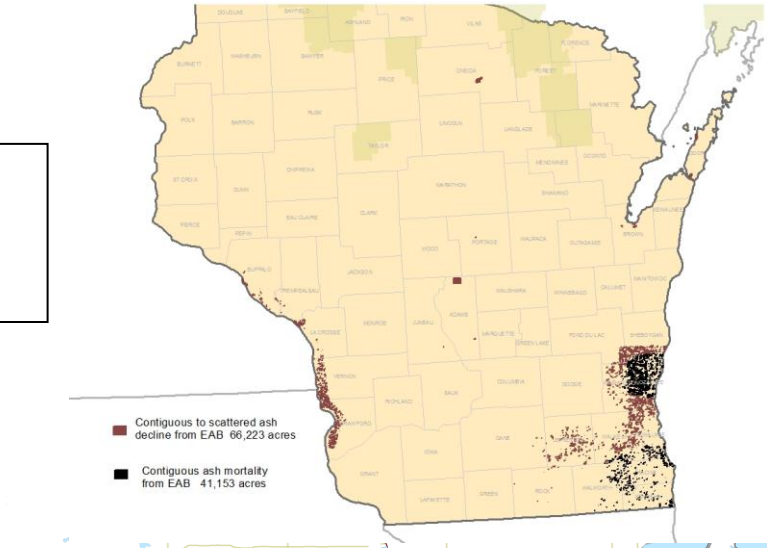


Figure 10. 2016 damage from EAB to ash. Crown decline predominated in areas tinted yellow. Mortality predominated in areas tinted red.

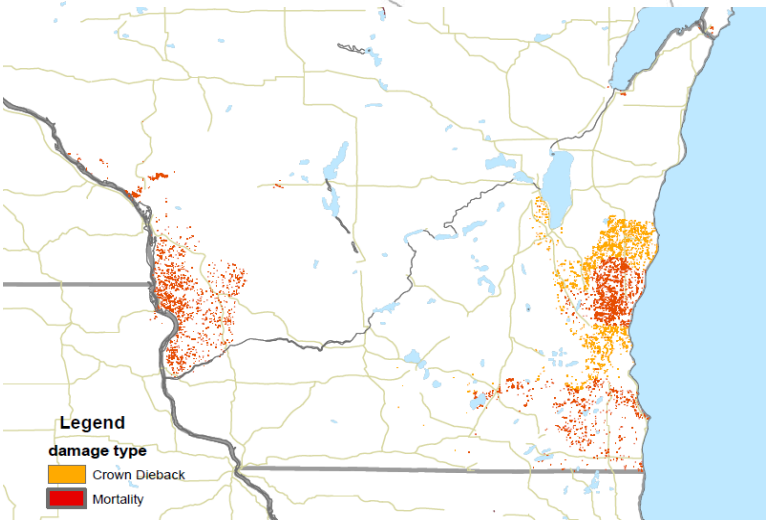


Figure 11. 2017 damage from EAB to ash. Area where damage occurred is overlaid with location of ash giving a stippled appearance. Crown decline predominated in areas marked in yellow. Mortality predominated in areas marked in red.

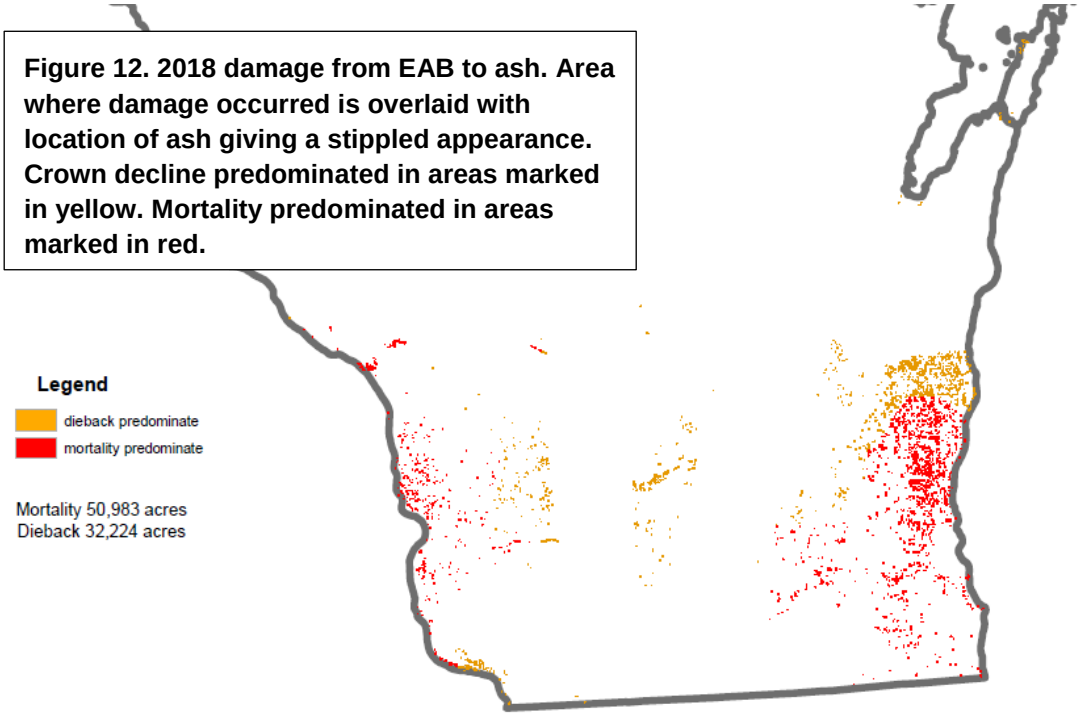


Figure 12. 2018 damage from EAB to ash. Area where damage occurred is overlaid with location of ash giving a stippled appearance. Crown decline predominated in areas marked in yellow. Mortality predominated in areas marked in red.

Biological control of EAB

2019 is the ninth consecutive year in which DNR staff and municipal cooperators released natural enemies of EAB in Wisconsin. Between mid-June and early October, staff released the larval parasitoids, *Tetrastichus planipennisi* and *Spathius galinae*, as well as the egg parasite *Oobius agrili*. These tiny wasps do not sting or bite people, and the public is unlikely to ever see them (Figure 13). These specialist parasitoids are introduced with the expectation that they will provide downward pressure on EAB populations in the future, allowing the survival of ash trees with partial resistance to EAB. Parasitoids are reared by the USDA APHIS Plant Protection and Quarantine EAB Parasitoid Rearing Facility in Brighton, Michigan. The wasps are supplied to states with established populations of EAB at no cost.

First releases were done in Dodge and Manitowoc Counties in 2019. Additional releases were done in seven counties where wasps had been released in prior years. Wasps have now been released in 20 of Wisconsin's 72 counties (Figure 14). Total wasp numbers released in 2019 were: 30,471 *Tetrastichus planipennisi*; 13,821 *Oobius agrili*; and 9,613 *Spathius galinae*.

Figure 13. *Tetrastichus planipennisi* wasps shown next to a penny for size comparison.

Parasitoid recovery surveys begin two to three years after introductions to allow released parasitoid populations to increase to detectable levels. This year, recovery surveys were done at two sites in Fond du Lac and Sheboygan Counties, but no *T. planipennisi*

or *S. galinae* wasps were recovered. Tree bark from the Sheboygan County recovery survey site is currently being incubated to attempt to recover *O. agrili*. Parasitoids have been recovered at release sites in previous years in Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha counties.

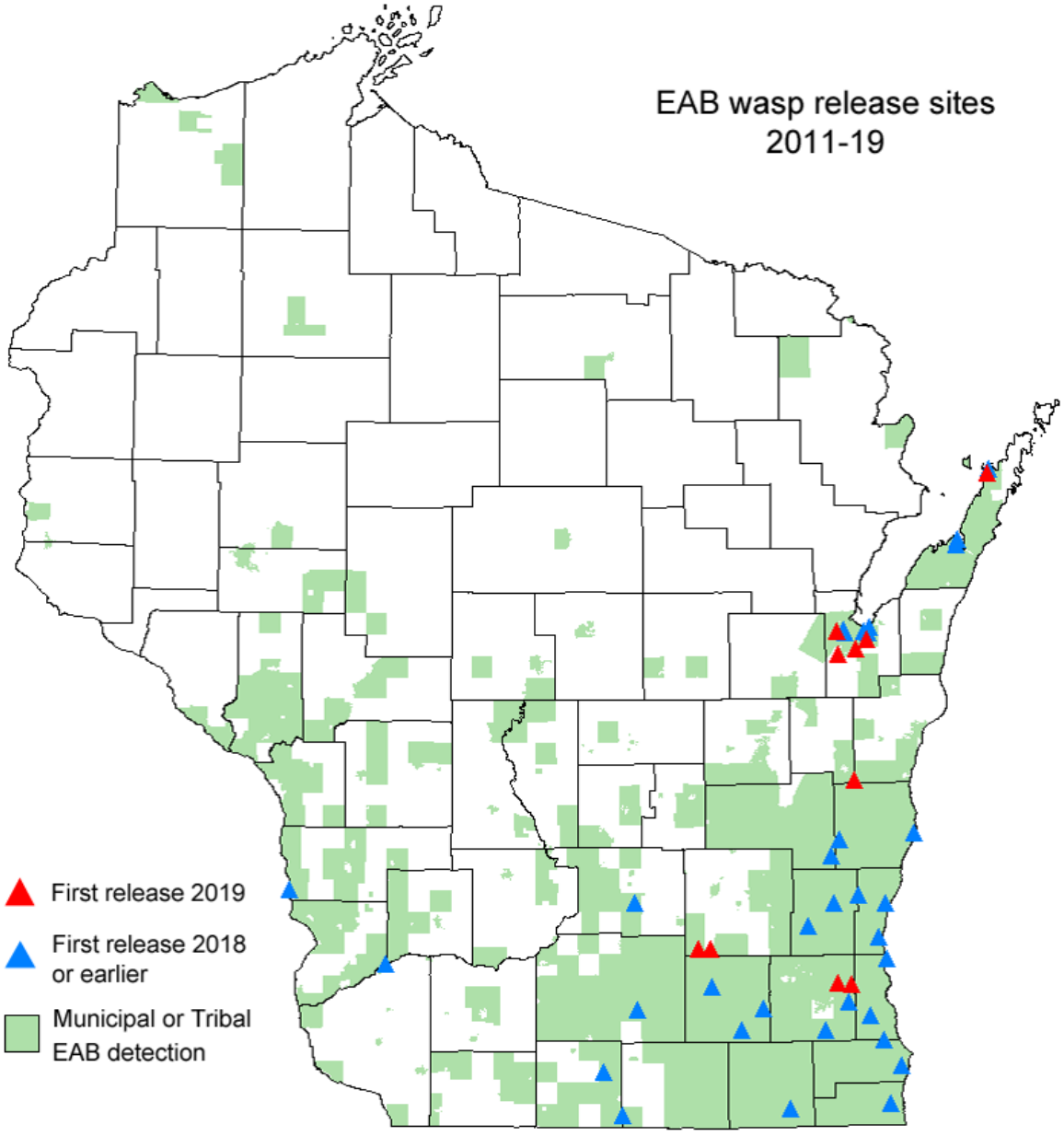


Figure 14. Map of release sites of EAB biocontrol agents 2011-2019 overlaid on locations where EAB has been confirmed present.

Gypsy moth (*Lymantria dispar*)

Gypsy moth is established in the eastern two-thirds of the state and 50 of Wisconsin's 72 counties are quarantined (Figure 15). Wisconsin's DATCP Slow the Spread (STS) program found reproducing but isolated populations in 10 non-quarantined counties. Those locations will be treated to reduce populations to levels where they cannot contribute to spread. Typically, a county is quarantined only when the STS program no longer treats reproducing populations detected there.

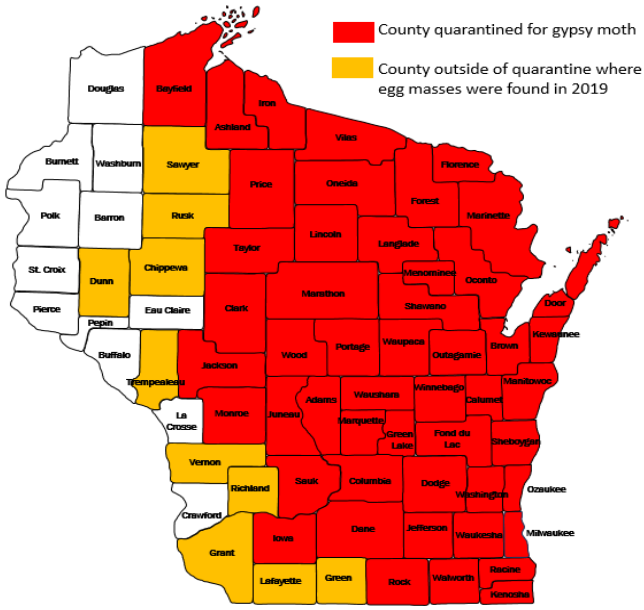


Figure 15. Wisconsin counties quarantined for gypsy moth (in red) and those outside the quarantine where egg masses were found in 2019 (in yellow).

Populations of the gypsy moth remained very low in 2019 and no damage was recorded outside of a few yard trees (Figure 16). Moth catch by the Slow the Spread trapping program in the western half of the state was down for the second year. Extremely cold temperatures in late January and a wet, cool spring which favored pathogens of the insect may have contributed to this decrease in the population of gypsy moth statewide.

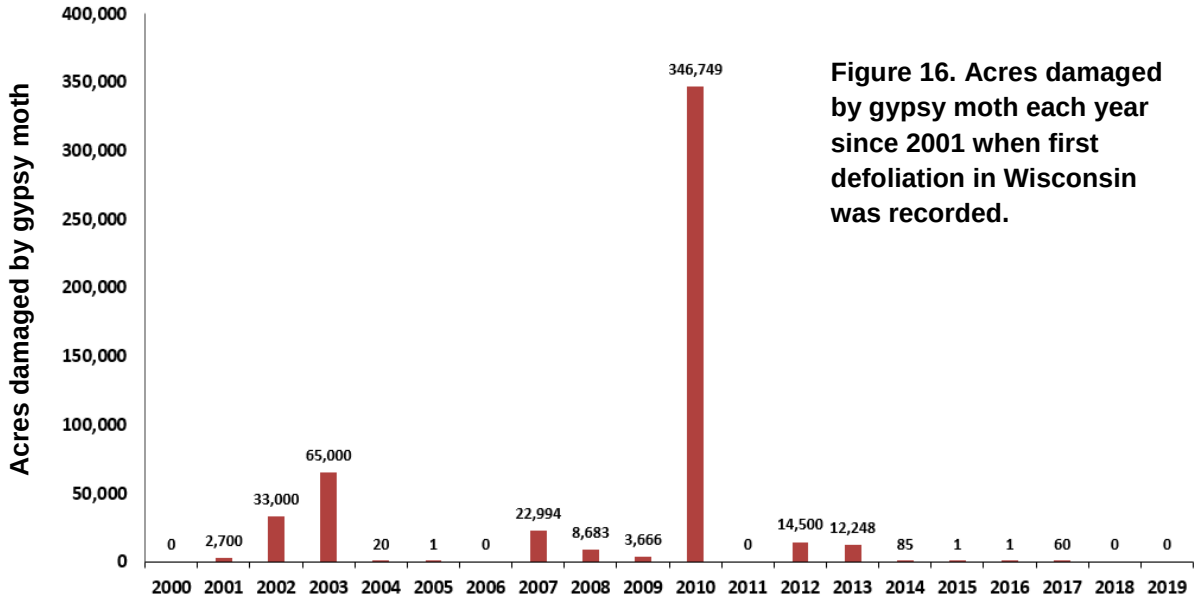


Figure 16. Acres damaged by gypsy moth each year since 2001 when first defoliation in Wisconsin was recorded.

Heterobasidion root disease (HRD, *Heterobasidion irregulare*)

Heterobasidion root disease (HRD), caused by the fungus *Heterobasidion irregulare*, is one of the most destructive conifer diseases in temperate regions of the northern hemisphere. Trees with HRD exhibit thin crown, growth loss, wood decay and/or mortality. Mortality often occurs as an expanding pocket of dead trees. The pathogen is both an immediate and long-term concern because it can persist in a stand, making it difficult to regenerate the stand to desirable species.

HRD was first detected in Wisconsin in 1993 in Adams County. It is currently found in 28 out of 72 counties in the state. (Figure 14). Most infections in Wisconsin occur in red and white pine plantations. However, the new site confirmed this year in Stevens Point, Portage County was along a recreational trail bordering a river.

Wisconsin requires use of preventive stump treatment guidelines on DNR-managed state lands and recommends their use on other lands. In 2017, a committee of stakeholders began an update of the current HRD guidelines. The committee reviewed recent research studies and surveys and evaluated the operational practicality of treatments in the field. Public comments were solicited in September 2018. The revised guidelines were approved and implemented in January 2019.

Research on HRD

Wisconsin DNR forest health staff worked with researchers at the University of Wisconsin – Stevens Point and Michigan State University to evaluate regeneration in HRD-infected red pine stands in Wisconsin and Michigan. The work was funded by an Evaluation Monitoring grant from the U.S. Forest Service. Results indicate that most sites will likely convert to hardwoods over time due to understory pine mortality. The study has been accepted for publication in 2020 in Forest Science by Demchik et al.

A study led by researchers at the University of Wisconsin-Stevens Point and Michigan State University, with collaboration with staff from the DNR's of Wisconsin and Michigan, investigated the efficacy of Cellu-Treat® and Rotstop™C, commercially-available fungicides to prevent the spread of HRD. This study is funded by a Pesticide Impact Assessment Program grant from the U.S. Forest Service. It is anticipated that this study will be complete in 2020.

HRD is a disease with a short history in Wisconsin. Found for the first time in 1993, its spread has caused concern and a need for a better understanding of the factors influencing that spread. This year, the forest health program contracted with Dr. Patrick Tobin at the University of Washington to estimate establishment patterns and spread of HRD in Wisconsin, evaluate the relationship between stand characteristics and establishment of HRD in Wisconsin, and model the risk of infection at a given geographical area in Wisconsin in the absence of management interventions. This work is expected to be completed in 2020.

Invasive plant suppression program

Amur cork tree (*Phellodendron amurense*)

Regulated in Wisconsin under NR40, Amur cork tree has been a focus of attention by invasive plant specialists in the forest health program for several years. This tree is regulated at the most restrictive level of Prohibited, which requires eradication where found. An exception to the rule is made for male cork trees which were thought to be unable to produce seed when the exception was given in NR 40. Since 2015, staff in the forest health program have investigated reports and surveyed for this tree and it has become apparent that it is much more widespread that formally thought. The tree is now known to occur in 27 counties (Figure 17). Most Amur cork trees are in residential areas as male cork trees are legally planted as street and yard trees. However, a disturbing number are present in wooded lands where they compete with native trees.

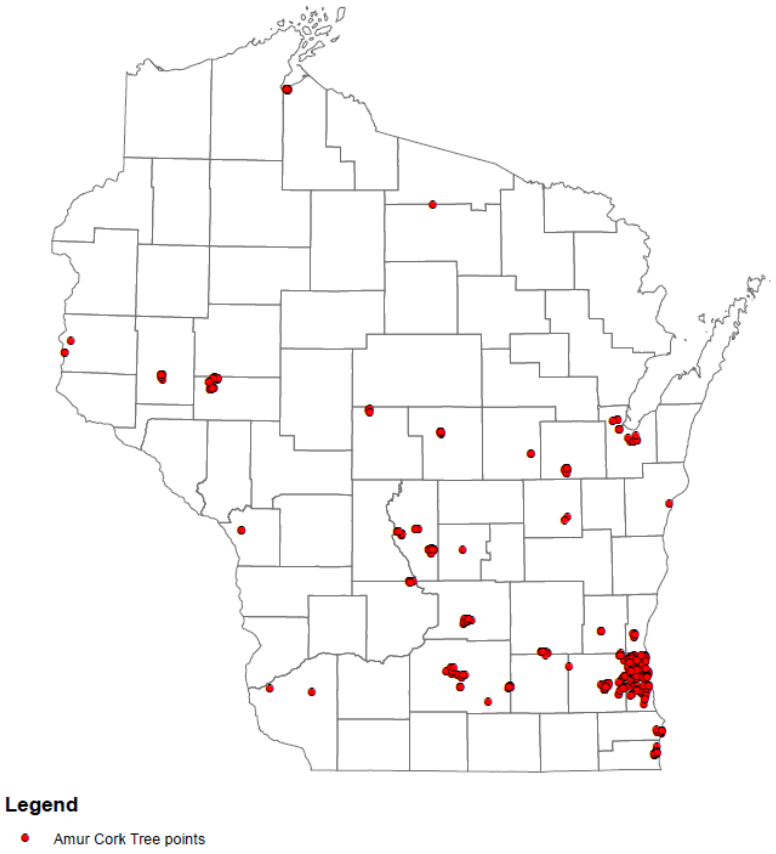


Figure 17. Known distribution of Amur cork trees in 2019.

In 2017, the forest health program received a grant from the U.S. Forest Service for control of the cork tree. State invasive plant suppression grant funds were used as match for this grant. Wild populations of the tree were controlled in five counties: Dunn, Adams Oneida, La Crosse, and Marquette. The highest priority site treated in 2019 was in Oneida County, where a large population of cork trees was identified on private property within the Northern Highlands American Legion (NHAL) State Forest. The cork trees had already spread throughout the private property and a single cork tree was found approximately 1.5 miles away, within the NHAL. Due to the threat this population posed to the surrounding state forest, it was prioritized for control. Hundreds of Amur cork trees of all sizes were removed from the property, and the landowner has agreed to continue to monitor and control any seedlings that will likely emerge in the future. Reconnaissance surveys are planned for 2020 at additional high-risk locations within the NHAL as the cork tree was present at high numbers long enough for it to have been introduced at multiple sites in the state forest by birds eliminating seeds of fruit they had eaten.

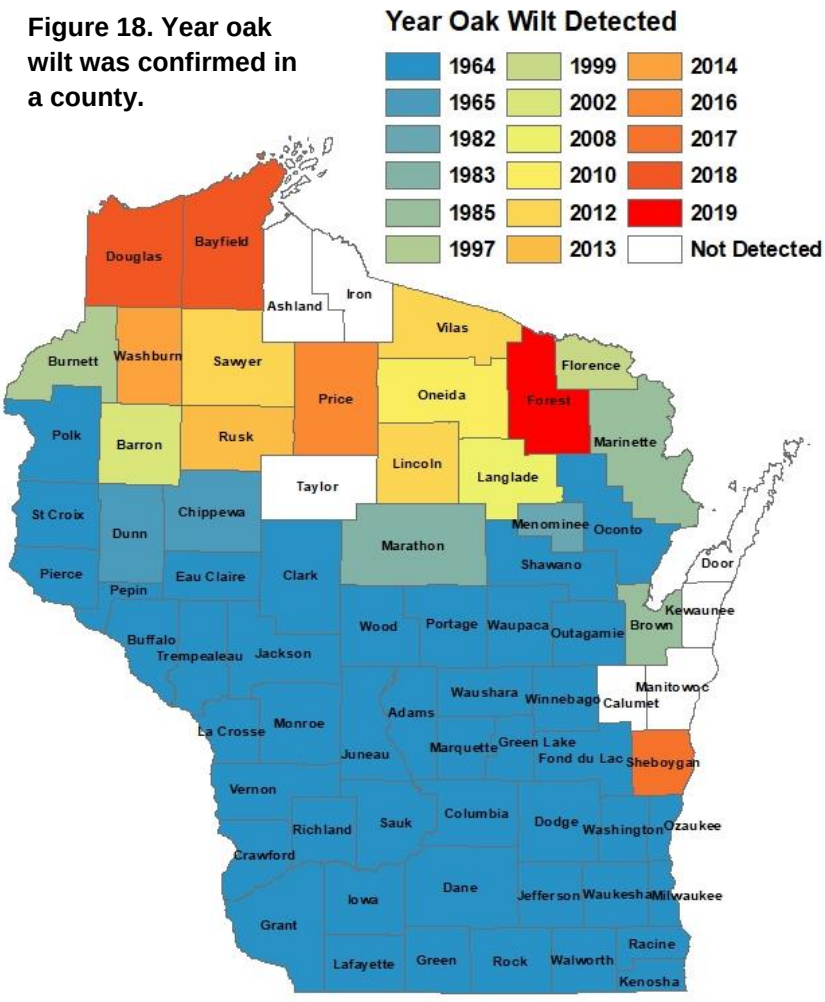
Oak wilt (*Bretziella fagacearum*)

Oak wilt disease is caused by the pathogenic fungus *Bretziella fagacearum* (previously known as *Ceratocystis fagacearum*). It kills oaks in the red oak group within the year of infection. Oaks in the white oak group can compartmentalize the disease but may also succumb from the infection over time. This disease is actively managed throughout Wisconsin.

History in Wisconsin

Oak wilt was first reported in Wisconsin in the early 1940's but was documented killing red oaks as far back as 1881. Once initial detection occurred and symptomology was better understood, there were more reports from counties in the central and south-central portion of the state. In the southern part of the state in the late 1940's, it was noted that oak wilt was having a distinct negative impact on oak savannah ecosystems in the absence of fire. It was predicted that oak wilt was present even before settlement, and it explained why oak savannahs are dominated by bur and white oak, containing far less oaks of the red oak group. Origins of the fungus are still not definitively known; however, it is suggested that due to the limited genetic variation of the fungal species, it is likely not a native pathogen but may have evolved in Central or South America.

Figure 18. Year oak wilt was confirmed in a county.



The first county-level oak wilt distribution map in Wisconsin showed that the disease was present in the lower 2/3 of the state by 1964. Northward spread appeared slow during the 1970's through 1990's but seemed to increase in pace since 2000 (Figure 18). In 2019 the disease

was found in Forest County for the first time in the Town of Lincoln. Oak wilt is now known to be present in all but 7 counties in the far north and the Door Peninsula. However, oak wilt is still uncommon in much of northern Wisconsin (Figure 19). Oak wilt was confirmed in five new townships in counties where it was previously detected: Madge (Washburn Co.), Namakagon (Bayfield Co.), Norrie (Marathon Co.), Sugar Camp and Hazelhurst (Oneida Co.) Why the disease has not advanced into the Door Peninsula and adjoining counties along Lake Michigan is not known.

In 2016, the WDNR Forest Health Lab started using a molecular test to diagnose oak wilt in addition to the traditional culture test speeding up the process of confirmation and allowing testing of samples not suitable for culturing.

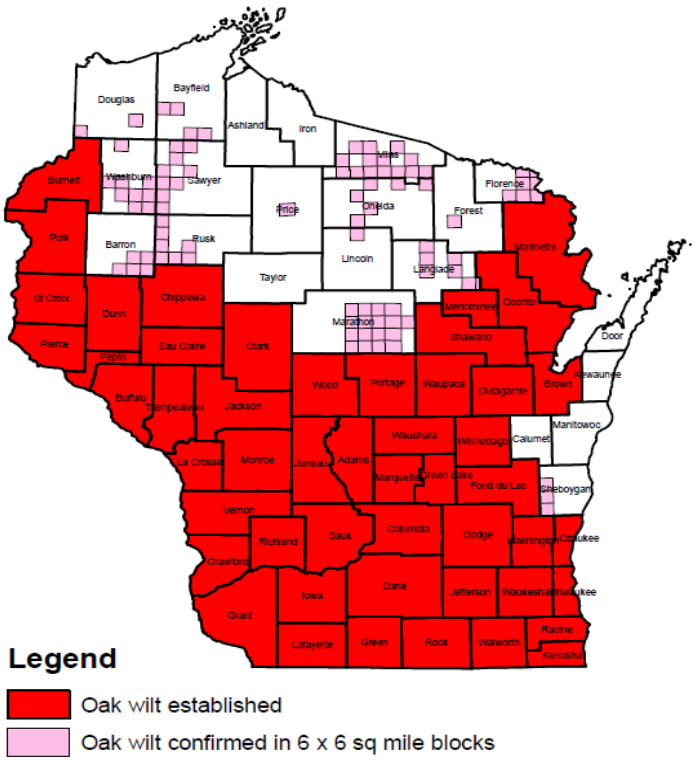


Figure 19. Oak wilt is generally established in counties tinted red. It has been confirmed in townships tinted pink in otherwise non-infested counties. Dec. 2019.

<u>Prevention of infection and spread</u>

In woodlots

Based on the biology of oak wilt, recommendations on seasonal limitation of pruning/harvesting oaks have been provided by forest health program staff for over 40 years. Initial recommendations focused on dates when risk of overland transmission was highest without consideration of other factors at the stand level that influence the risk of oak wilt infection or its consequences. For example, harvesting an oak stand during the period of high risk of transmission would have no consequences and could occur if the stand is being converted to pine. To develop recommendations that took such stand level situations into account, an oak wilt committee comprised of stakeholder groups was formed in 2005. The committee developed a statewide system for oak wilt risk analysis based on scientific- and experience-based knowledge. Stand-level recommendations for seasonal timber harvest activities in oak stands were developed based on the results of risk analysis, and the risk-based guidelines were implemented in March 2007. In 2014-2015, the guidelines were thoroughly reviewed by the stakeholder oak wilt advisory committee and sub-committees, and updated using recent

research findings, experience gained in implementation of the guidelines, and economic considerations. The revised guidelines were implemented in January 2016.

Along powerlines, roads and in communities

Following instances where oak wilt was spread along powerlines and roads following clearing activities, stakeholders worked together to develop guidelines, rules, ordinances, and recommendations to prevent the spread of the disease and loss of oaks in developed areas. In 1995, a cooperative effort between the Wisconsin Public Service Commission, the Wisconsin Utilities Association Rights-of-Way Maintenance Committee and the WDNR was initiated to develop guidelines for Wisconsin's electric utilities to use during line clearing. PSC (Public Service Commission) 113.0511 was established in July 2001 to provide the rules related to oak tree cutting and pruning which investor-owned electric utility companies are required to follow. Wisconsin Department of Transportation has included similar practices in order to prevent the spread of oak wilt in the State of Wisconsin Standard Specifications for Highway and Structure Construction. Several municipalities have implemented oak wilt ordinances limiting when oaks may be pruned to prevent spread of oak wilt within their communities.

Control

The spread of oak wilt within a stand through root grafts can be contained by severing those root connections. Using a model of underground spread developed by Johann Bruhn, trenching is done encircling both trees showing symptoms of infection and those that are likely to be infected though they may show no symptoms. This has typically been done by using a vibratory plow or a trencher. However, trenching can't be done in stony soils and is expensive so is not typically affordable for control in woodlots. As an alternative, root grafts may be torn apart by pulling stumps from the ground using an excavator or pushing trees over with a bulldozer. This does require enough space between trees to negotiate the heavy equipment as well as the cost of the use of the equipment itself. Managers of oak dominated stands in Wisconsin needed a method to contain oak wilt spread through root grafts that is inexpensive and doesn't require mechanized equipment. The use of herbicides to create a buffer of dead roots between infected and healthy oaks was first used in Wisconsin by Thomas Meier, a consulting forester. Live trees are girdled with a chainsaw then herbicide is applied to kill the tree. Like trenching, both infected and apparently healthy trees are treated to form a buffer free of live, grafted roots between the infection and the rest of the stand. This technique has been used with success since 2003 in the Marathon County Forest and more recently in federal, state, county, tribal, and private lands. To formally test this technique and make its use eligible for grant support from the USDA Forest Service, in 2015 DNR staff started a 5-year study to evaluate the effectiveness of this method. The field work was concluded this year, and data analysis is in progress.

White pine bast scale (*Matsucoccus macrocicatrices*) and the canker disease (*Caliciopsis pinea*)

White pine bast scale (*Matsucoccus macrocicatrices*) and a canker disease caused by *Caliciopsis pinea* may be agents in an insect/disease complex that causes branch mortality in large white pines. Both white pine bast scale and Caliciopsis canker are relatively new issues in this state, with the first observations being made on pole-sized white pine in northern Wisconsin in 2018. In 2019 scales and the canker were associated with dying branches on white pine in Marinette, Oneida, and Vilas Counties (Figure 20).

White pine bast scale, a native insect, is tiny, black, oval-shaped, and lacks both eyes and legs (Figure 21). It uses a long stylet to siphon sap from outer layers of phloem (bast) of twigs and branches. White pine bast scales can often be found under lichens on white pine branches; the lichens don't directly harm trees but they can provide shelter for scale insects. In 2019 white pine bast scales were also found on twig tips at bud scars or at the base of needle clusters.

White pine bast scale by itself has not previously been known to cause problems in white pine but it appears that the combination of the scale insect with the Caliciopsis canker can cause branch mortality. This damage typically begins on lower branches but may occur mid-crown as well. Symptoms of this insect/disease complex can be mistaken for the symptoms of white pine blister rust.

The fungal pathogen *Caliciopsis pinea* causes small cankers, which are dead spots in the tree's tissue, to form in the inner bark of trees; many cankers can develop on each branch. As more cankers develop, affected branches will eventually be unable to move water into foliage, which will die. It is believed that *Caliciopsis pinea* is associated with white pine bast scale, although other factors may be involved when branch mortality is present.

Figure 20. White pine bast scale and caliciposis canker can cause branch mortality.

Figure 21. White pine bast scale at the base of a needle looks like a small black seed.

Hardwood issues

Bur oak blight (*Tubakia iowensis*)

In 2019 this disease was confirmed in three new counties; Milwaukee, Green Lake and Columbia. Bur oak blight has now been confirmed in 30 counties in Wisconsin since it was first detected in 2010 (Figure 22). Bur oak blight symptoms are most common in the lower half of bur oak canopies. Wedge-shaped yellow and brown patches on the leaves and purple/black leaf veins are the most obvious symptoms of bur oak blight. Trees may decline over many years as the fungus that causes bur oak blight spreads through the canopy.

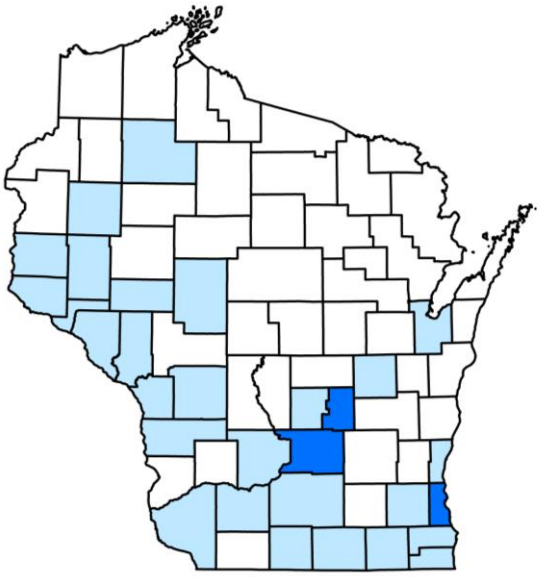


Figure 22. Counties where bur oak blight was detected in 2019 are tinted dark blue. Counties where it was confirmed in previous years are light blue.

Other oak health issues

A wide variety of oak health issues were observed in 2019. The tree health impact of these issues ranged from cosmetic foliar diseases, decline, and in some cases rapid mortality. Notable pests and pathogens involved in oak issues in 2019 were:

Botryosphaeria – This fungal pathogen infects and kills branch tips. Healthy oaks typically recover from the damage within a year or two.

Leaf fungal pathogens –Anthracnose, Monochaetia leaf spot, Sphaeropsis canker, Tubakia leaf spot. Precipitation well above normal levels during the entire growing season in 2019 favored these leaf pathogens. While they may reoccur yearly during wet periods, they generally do not impact the long-term health of trees.

Figure 23. Twig dieback from galling.

Galls on leaves and twigs – This year there were numerous reports of leaf and twig galls on white and bur oaks. These were caused by small wasps, including Cynipid gall wasps. Galls on twigs may cause some minor dieback of branch tips but are not considered a long-term health issue (Figure 23). Leaf galls cause only aesthetic injury.

Mature bur and white oak decline and mortality – Forest health staff in Minnesota and Wisconsin are getting reports of accelerated decline and mortality in mature (75+ years old) bur and white oaks. A decade of accumulated abiotic stresses such as

drought and flooding has allowed opportunistic pests and diseases to successfully infest and kill these trees that if healthy, would have been able to defend themselves.

Oak twig pruner – The larvae of this long-horned beetle tunnels through oak twigs, ultimately causing them to break off the tree. A healthy tree will incur only minor damage and easily recover.

Two-lined chestnut borer – TLCB is a wood-boring insect in the same group as emerald ash borer. It is a native pest however and can't successfully attack healthy, native oaks. TLCB is an opportunistic pest targeting stressed trees, often killing them over the course of several years. Stress factors currently affecting oaks that might also predispose them to TLCB attack include storm damage, flooding and old age.

Phytoplasma (*Candidatus Phytoplasma fraxini*)

Phytoplasmas are small bacteria that lack cell walls. They live as obligate parasites and plant pathogens. In trees, they can cause dense branch growth, broom formation of branches (witches' brooms), dwarfed or mis-shaped foliage, yellow or red foliage, decreased growth, vertical bark cracks, thin crowns, dieback and/or mortality. Due to foliage chlorosis often observed, phytoplasma is commonly referred to as "yellows disease".

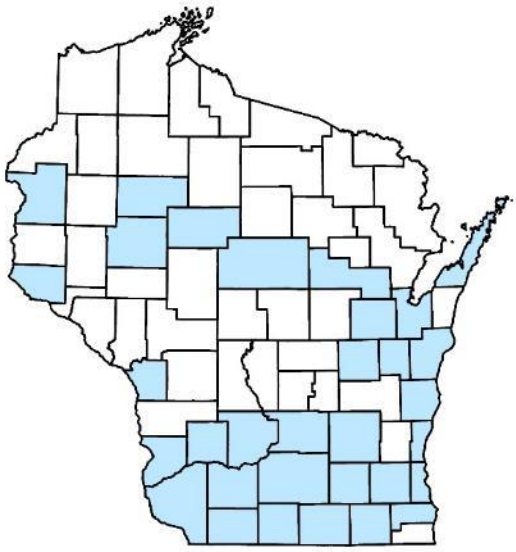


Figure 24. Counties in Wisconsin where phytoplasma has been confirmed are tinted blue.

The most commonly known phytoplasma disease in Wisconsin is ash yellows. This disease was first found in Wisconsin on white ash in 1987. Currently, phytoplasma has been confirmed in 32 counties in Wisconsin (Figure 24 and in 16 tree and shrub species using the genetic testing method of polymerase chain reaction (PCR). Host species detected with phytoplasma include American beech, ash (black, green, and white), black walnut, butternut, chokecherry, elm, hazelnut, bitternut and shagbark hickories, lilac, red maple, white mulberry, white spruce, and swamp white oak.

Wisconsin DNR Forest Health program partnered this year with University of Wisconsin Plant Disease Diagnostics Lab to further evaluate taxonomic characteristics of known or new phytoplasmas in Wisconsin. In previous years, this test was only able to identify to the Genus level of *Candidatus* Phytoplasma (*Ca.* P. sp.). But the new test is able to identify to the species level. The full results are pending but to date all ash species tested have been identified infected with *Ca*. P. fraxini. On black walnut, samples tested so far were confirmed with a different species, *Ca*. P. pruni. In 2019 we also had a new host species confirmation in Rock County of

Chokecherry, *Prunus virginiana*, infected with *Ca.* P. pruni. Additional host and phytoplasma species, groups, and subgroups are anticipated as testing is completed for this season. Asymptomatic plant samples and some insects are also planned for phytoplasma testing from this season with results expected in 2020.

Conifer Issues

Eastern larch beetle (*Dendroctonus simplex*)

Eastern larch beetle is a native bark beetle that attacks tamarack by tunneling under the bark, girdling and eventually killing the tree. Scattered damage and mortality from eastern larch beetle was first noticed in the state in 1999, and annual mapping efforts have continued each year since 2012. In 2019, 656 acres of scattered tamarack mortality were recorded in in Douglas, Florence, Forest, Langlade, Oneida, Sawyer, Vilas and Washburn Counties. Like other bark beetles, eastern larch beetle first attacks stressed trees, but as beetle populations build in a stand, a localized outbreak may occur and lead to death of most trees in a stand, even without additional stress-causing events. Inciting stressors may have included drought in 2012-13, larch casebearer defoliation in 2014, record rainfall throughout the growing season that flooded stands for extended periods in 2017, 2018 and 2019 and above-average temperatures over several decades. This combination of factors has created more favorable conditions for beetle overwintering survival and life-cycle development.

Pine wood nematode (*Bursaphelenchus xylophilus*)

Pine wood nematodes were found in summer 2019 infecting Scotch pine in Waushara County (Figure 25). Symptoms of pine wood nematode include rapid browning of the crown in late summer, rapid drying of wood, and presence of blue-stain fungi in the wood. This pest causes a severe disease of pine in Japan. Non-native pines planted in Wisconsin such as Scotch and Austrian are highly susceptible. However, pine wood nematode is not known to cause the same severe disease here in pines native to the Midwest. The Scotch pines infected with the nematode at the site were also heavily infected with diplodia fungi.

Figure 25. Scotch pine dying from pine wood nematode.

Pine wood nematode is native to North America and was first confirmed in Wisconsin in 1980. It has since been found across the state. This nematode is vectored and carried to susceptible trees by long-horned beetles as is the associated blue stain fungi on which the nematode feeds. Wisconsin's native long-horned beetles, such as the white spotted sawyer beetle, usually attack dying and dead trees suggesting that the potential for pine wood nematode to affect healthy native trees is relatively low.

Rhizosphaera on spruce (*Rhizosphaera kalkhoffii*)

Rhizosphaera needle cast impacted many forest and yard trees in 2019. The disease is favored by wet conditions and Wisconsin has experienced above average rainfall since 2016 and 2019 was especially wet. Colorado blue spruce are the most susceptible, but white and black spruce are also heavily impacted when conditions are continuously wet. Infected needles turn a dull purple-brown color and are prematurely shed. It is no longer rare to see the bottom quarter to three-quarters of a spruce retaining only one year's worth of needles or completely defoliated under high disease pressure.

State nursery studies

Asymptomatic infection by *Diplodia sapinea* in state nursery stock

Asymptomatic infection by *Diplodia sapinea* in red pine seedlings can result in failure of the plantation if the disease becomes symptomatic after planting. To prevent this, healthy-looking red pine seedlings from the Wilson State Nursery have been tested annually to assess for asymptomatic infection prior to sale. Asymptomatic infection rate must be 10% or less or the stock will not be sold.

In 2019, the infection rate for 2-year old seedlings (278 seedlings tested) was 7.6%. This was a disturbing increase in the asymptomatic infection rate of 2.7% of the same cohort as 1-year old seedlings in 2018 (223 seedlings). This 4.9% increase in infection is higher than the historical average for the same growth stage and investigation on potential cause(s) is in progress. The infection rate for 3-year old seedlings (270 seedlings tested) was 1.9% in 2019 down from 3.1% (382 seedlings tested) for that cohort in 2018. In October 2019, one-year old red pine seedlings had an asymptomatic infection rate of 1.4% (255 seedlings tested).

Survey of galls on jack pine seedlings at the Wilson Nursery

The incidence of galls on jack pine seedlings caused by rust fungi has typically been very low at the Wilson nursery and only one species of rust has been identified there, *Cronartium quercuum* (pine-oak gall rust). Annual Surveys conducted in 2009-2012 found a 0%-0.5% incidence rate on one-year old jack pine seedlings. In 2017 however, the rate of galling on one-year-old jack pine seedlings jumped to 2.9% (1000 seedlings sampled). In response, Wilson Nursery implemented fungicide applications to control this problem during the 2017 and 2018 growing seasons. In 2018, no galling was found in samples of 1000 seedings of each of the 1 and 2-year-old cohorts of jack pine. In April 2019, this survey was repeated for 1-year-old seedlings at the time of lifting and the gall incidence rate was 0.2%. In order to detect delayed symptom

development over the growing season, 100 apparently healthy, 1-year-old jack pine seedlings were randomly selected, potted, and grown on in a greenhouse. In November 2019, these seedlings were examined for presence of galls. Only one seedling was galled out of the sample of 100, a 1% rate of galling. Based on this result, monitoring for galling will be repeated among the 1-year-old cohort of seedlings lifted in spring 2020.

Fumigant study – preliminary report

The Montreal Protocol requires the phasing out of the use of methyl bromide in nursery production except for quarantine required, pre-shipment treatments. The Wilson State Nursery made the decision in 2013 to switch to metam sodium for fumigating seedling beds prior to planting to eliminate soil-borne pathogens and weeds. Following this switch in soil fumigant, the nursery experienced unacceptable mortality and slow growth of seedlings. In 2016, a study to evaluate the effect of different fumigants on the survival and growth rate of tree species grown at the nursery was initiated. Each of three nursery beds was divided into four blocks. Each block was treated with one of the following treatments:

- Methyl bromide (66%) and chloropicrin (34%), applied in September 2016
- Chloropicrin only, applied in September 2016
- Metam sodium, applied in August 2016
- No fumigant control

Jack pine, red pine, white pine, and white oak seeds were planted in October 2016. Germination rate was recorded in spring of 2017 and growth (height, caliper, dry weight) of sampled seedlings were measured at the time of lifting.

Results from analysis to date,

- Red pine
    - germination rate was significantly lower in chloropicrin treated blocks than in those treated with metam sodium or the control.
    - By 2019, average height of red pines was significantly taller in blocks treated with either methyl bromide and chloropicrin mixture (P=0.03) or chloropicrin only (P=0.02), compared with no fumigant control. The height of RP in blocks treated with metam sodium was not significantly different from the no fumigant control.
- Jack Pine
    - By 2018, average height of jack pine with chloropicrin treatment was statistically taller than no treatment (P=0.01).
- White pine
    - Aboveground dry weight of seedlings from blocks treated with metam sodium was significantly lower than for seedlings in other treatments.

As part of the study, soil samples were taken before and after fumigation to quantify the population of *Fusarium* spp. in the fall of 2016, and spring of 2017. There was no difference in

populations of *Fusarium spp.* between treatments and the no fumigant control. Species of *Fusarium* detected included *F. solani*, *F. oxysporum*, and *F. fujikuroi*.

Spruce budworm (*Choristoneura fumiferana*)

Defoliation of spruce and balsam fir due to spruce budworm (*Choristoneura fumiferana*) in 2019 was locally patchy with moderate to heavy defoliation in Bayfield, Douglas, Forest, Marinette, Oconto, and Vilas Counties. The trend from 2016-2018 had been steadily decreasing amounts of defoliation, but this year saw some increase in defoliation levels although it was very patchy.

Figure 26. Spruce budworm larvae and feeding damage.

Similar to 2018, growth rates on trees were generally good, which gave a greener look to the forest even though spruce budworm was still causing defoliation (Figure 26). In areas of Bayfield, Douglas, Forest, Marinette, and Vilas Counties, where multiple years of defoliation has occurred, top kill and whole tree mortality of balsam fir is occurring.

Regional budworm outbreaks occur every 30-50 years and can last 10-15 years. Wisconsin's last outbreak ran from 1970 to 1980. Mature balsam fir and spruce are the primary targets, although younger balsam or spruce can be defoliated as well. Repeated defoliation can cause top-kill and eventually whole tree mortality. Our current outbreak appears to have started in 2012, so several more years of defoliation may still occur.

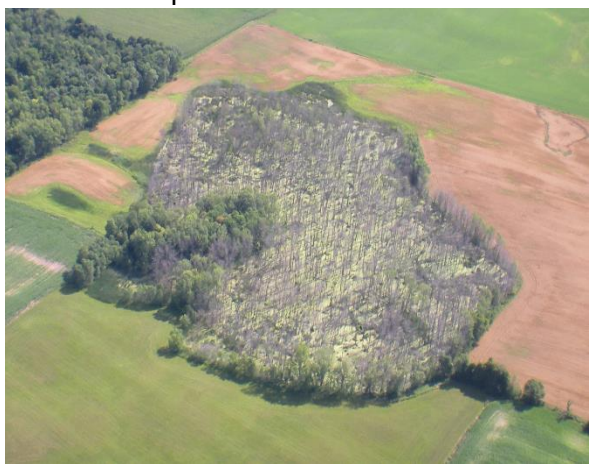


Figure 27. Heavy tree mortality in a lowland site, standing water was present on July 31. Note surviving trees on higher ground and in adjacent stand.

Abiotic Issues

Temperatures were below average from January through June 2019. Exceptionally cold temperatures in late January with little snow cover caused tree root injury leading to decline or mortality later in the year. The species of trees and shrubs impacted, and the level of damage

varied widely across the state. Temperatures during the summer fluctuated slightly above or below average (Wisconsin Climate Watch).

2019 was the wettest year on record for Wisconsin, precipitation levels were well above average across Wisconsin for most of year (Figure 28). This is the third consecutive year of above average precipitation causing lake, river, and ground water levels to rise significantly. Flood caused mortality of forests continues to increase from both flash flooding following heavy rain as well as in seasonally wet areas that have remained flooded during the growing season in 2019 and the past two years (Figure 27). Even flood tolerant species such as silver maple are being impacted. Premature color change indicative of stress has also been noted in many flooded forests. Combined stress from EAB and flooding may be accelerating decline in ash in the infested southern third of the state and the Door Peninsula. There have been many reports of previously forested wetlands converting to cattails, canary grass and sedge growing into wet sites previously forested by smaller ash and elm (see cover image).

The most significant weather event of 2019 was a major storm system that passed through Wisconsin July 19-20 that caused more than 286,000 acres of wind damage to forests in Polk, Barron, Sawyer, Langlade, Oconto, Oneida, Outagamie, Wood, Portage, Marathon, and

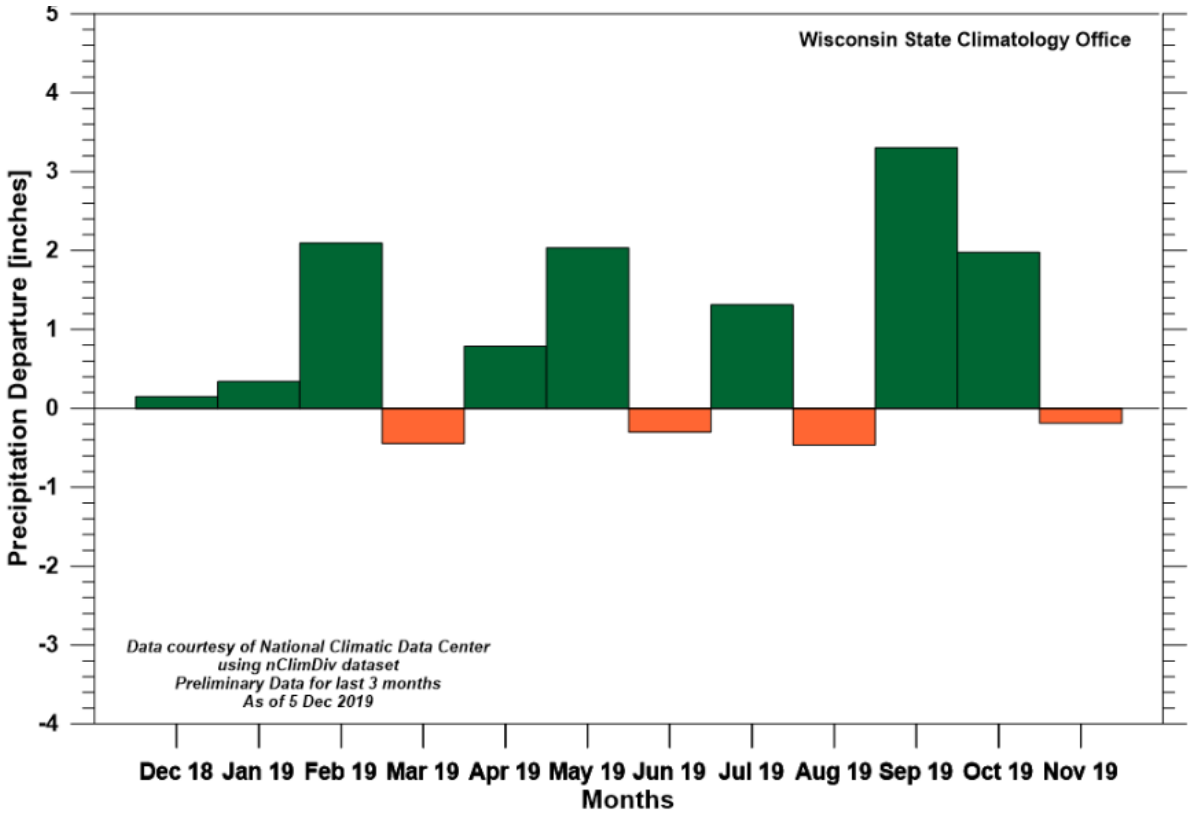


Figure 28. Wisconsin statewide monthly precipitation departures from 1981-2010 normals for Dec 2018-Nov 2019.

Waupaca Counties (Figure 29). More information at dnr.wi.gov keyword ‘storm’. An F-3 tornado on September 24th caused approximately 1500 acres of damage in Chippewa County.

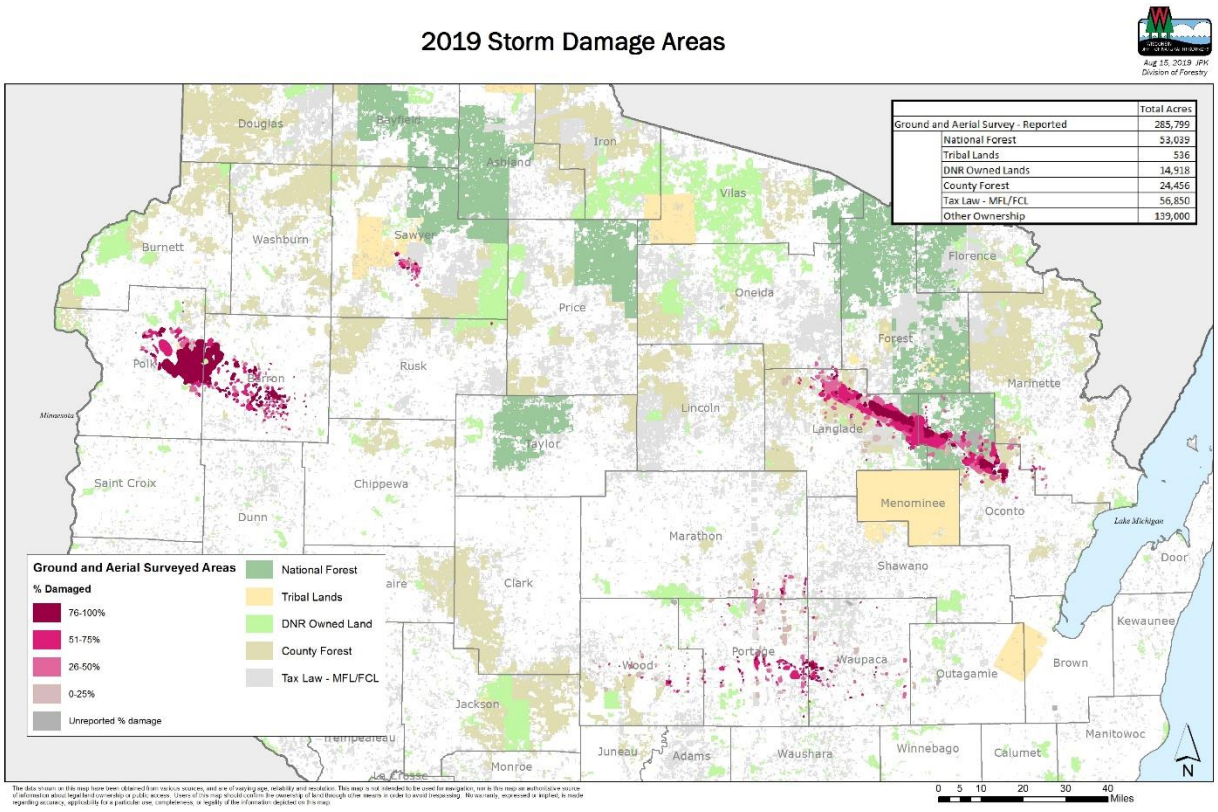


Figure 29. Map of areas damaged by the storm system that passed through Wisconsin July 19-20, 2019.

Acknowledgements

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